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CONTROL OF MOLDING PASTES FOR AN ABRASIVE TOOL MADE OF SILICON CARBIDE AND ELECTROCORUNDUM MICROPOWDERS IN A CERAMIC BINDER

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The possibility of using a small VIMS-1 device for measuring the electrophysical properties of abrasive molding pastes made of micropowders in developing formulas for an abrasive tool and for controlling the quality of the pastes in production conditions was examined. It was shown that introduction of control of the electrophysical properties of molding pastes is a real possibility for obtaining molding pastes of stable quality.

The manufacturing process in production of an abrasive tool made of silicon carbide and electrocorundum micropowders in a ceramic binder is very complex and the requirements dictated by metalworking conditions for the quality and stability of these articles are high. It is possible to improve product quality by raising the level of quality control of conducting the manufacturing process and the costs of mastering new methods of control of the initial raw material and respecting the conditions of the manufacturing process are almost always quickly recovered by decreasing rejects and the stability of product quality.

Based on research on production technology for abrasive articles and ceramic articles with similar properties molded by semidry molding, it is possible to truly say that the properties of the raw materials and molding pastes are the most important factors that affect the final properties of abrasive articles made from micropowders.

A comparative analysis of silicon carbide micropowders from different manufacturers and the articles made from them revealed the following. Silicon carbide micropowders can satisfy the requirements of the manufacturing conditions with respect to the chemical composition and impurity content and still (within the framework of the same grain size) differ significantly in granulometric composition [1]. The observed differences in the granulometric composition of micropowders affect the character of the behavior of the silicon carbide grains in firing. For this reason, such parameters of the standard manufacturing process as the content of components and tool firing conditions must be corrected. This is because the resistance to heating (oxidation) of silicon carbide grains is a function of their size, while the amount of silicon oxide grains formed on the surface affects the overall structure and density of the articles and the cutting properties of the tool. Introduction of input control of the grain composition of the micropowders and conducting the manufacturing process in accordance with the granulometric composition of the silicon carbide are mandatory conditions for stable tool quality.

The results of studying molding pastes for an abrasive tool made of electrocorundum and silicon carbide micropowders in a ceramic binder are reported here. The abrasive molding pastes consist of an abrasive material, a ceramic binder containing clay and feldspar, water, and a temporary binder — dextrin. Molding pastes acquire the required structural and mechanical properties during mixing, wetting with water, and ripening. The ratio of the basic components in the paste, the amount of water, and the conditions of mixing the components of industrial compositions were established in laboratory conditions for each granularity of the abrasive material and brand of ceramic binder based on the results of determining the mechanical breaking strength of freshly molded samples of the raw material for abrasive articles [2].

Too much or too little moisture in the molding paste affects the rheological properties of the paste. With insufficient moisture content, hydration of the components and formation of bonds between the particles in the paste do not take place

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Fig. 1. VIMS-1 instrument.

completely, the raw material has low strength in this case, and the articles will crumble. If the content of free water in the paste is higher than necessary, during molding, the raw material and then the article will have too high density. Determining the breaking strength of the raw material is a very lengthy process, and not all enterprises have the necessary equipment. Due to variations in the composition and properties of the raw material, the humidity in industrial premises, and many other factors, the recommendations developed in laboratory conditions, primarily based on the experience of the executors, are almost always corrected in production conditions. The method of controlling molding pastes for their water content, determined by drying to a constant weight, used in some enterprises is not an indicator of the quality of the paste.

Molding pastes acquire the required properties after addition of water. Due to hydration of the surface of the clay and abrasive particles, hydration shells and electric double layers that ensure formation of strong bonds between the particles in the paste are formed [3]. The electrophysical properties of the paste probably also change. Our problem consisted of determining the possibility of measuring the electrophysical properties of molding pastes and evaluating this parameter for diagnosis of the quality and readiness of the molding paste for molding.

The measurements were performed with a VIMS-1 instrument (Fig. 1), developed for monitoring the moisture content of construction materials. This is a small device convenient for fast control, and the measurements take a few minutes. A dielcometric method of controlling electrophysical properties is implemented in the VIMS-1. The instrument measures the characteristic high-frequency field of a variable-capacitance transducer in which a sample of the investigated material is inserted. The voltage *U* on the capacitor plates of a pickup transducer (pickup) is used as the parameter measured in this model of the instrument, and its value is a function of the dielectric constant of the object controlled introduced in the field of the transducer. Since the dielectric constant of water is higher than for such materials as wood, sand, cement, and clay, the moisture content can be judged by the change in the dielectric constant [4]. Calibration curves for converting the instrument's readings into moisture content indexes have been established for construction materials.

The components of abrasive molding pastes differ from construction materials in the electrophysical properties. In addition, a specific feature of abrasive pastes is that the paste can ensure high strength of the raw material at a relatively low density (given porosity of the articles of 45 – 55%), and for this reason, the regimes and conditions were developed for measuring the properties of abrasive pastes that ensure reproducibility of the results of the measurements and minimize the sampling error. Testing the VIMS-1 in measuring the properties of multicomponent abrasive pastes [5] showed that data can be obtained with this instrument on the change in the electrophysical properties caused not only by molecular water but also by hydrated layers on the particles in the molding pastes. This practically means that the occurrence of hydration, which essentially provides the plasticity of the paste necessary for molding abrasive articles and strength of the raw material, can be characterized by the change in the electrophysical properties.

The most complicated molding pastes for manufacturing made from silicon carbide and electrocorundum micropow-

TABLE 1

Material	VIMS-1 readings (*U*, V) for materials				
	initial	initial + 5% H_2O	initial + 10% H_2O	during drying	after drying
Silicon carbide with granularity M14	0.50 – 0.52	1.93 – 2.06	–	0.77	0.62
Electrocorundum with granularity M20	0.18 – 0.19	–	1.34 – 1.79	0.25	0.18 – 0.19
Silicon carbide with granularity 6	0.65 – 0.68	–	3.25 – 3.28	1.35 – 2.00	0.60
Electrocorundum with granularity 40	0.19 – 0.24	0.79 – 0.84	–	0.32	0.22 – 0.23
Potato dextrin	0.14 – 0.22	–	–	–	–
K3 binder	0.20 – 0.22	–	–	–	–
K20 binder	0.07 – 0.09	–	–	–	–

ders were selected for the study. Molding pastes of standard compositions were investigated; they differed in the abrasive material, particle size, and consequently, preparation scheme — mixing, wetting, and ripening. As a result of measuring the electrophysical properties of the initial components of dry and wet molding pastes and the properties of dried materials (Table 1), we found that the coarser the abrasive material, the higher the instrument's voltage readings. In addition, the instrument's readings for silicon carbide were significantly higher than for electrocorundum, and in the standard measurement circuit almost went beyond the boundaries of the instrument's working range. For this reason, a special measurement circuit with a dielectric protector was developed to measure the properties of silicon carbide pastes.

Abrasive molding pastes are multicomponent mixtures and in order to follow the effect of each component on the change in the electrophysical properties of the pastes, the measurements were performed successively in each stage of the process (Table 2). The measurements were performed not only on pastes suitable for molding but the indexes of pastes that had lost plasticity (overdried pastes) were also measured. In addition, the electrophysical parameters of pastes that differed in the ripening and storage conditions were also measured. Due to the compactness of the VIMS-1 and the specially developed fast-control circuit, it is possible to perform the measurements in production conditions. This allows determining the range of readings of the instrument for paste samples from different parts of the storage container and to observe the change in these readings in working with the paste.

Adding water to the abrasive materials increased the instrument's readings by 5 – 6 times; after drying, electrocorundum had almost the same parameters, while an increase in the readings was characteristic of silicon carbide micropowders. The mixture of the abrasive materials, binder, and dextrin was characterized by a value close to the calculated value. In wetting with water, the instrument's readings increased by more than 3 times — from 0.2 to 0.7 V for silicon carbide paste with granularity M14 and from 0.2 to 0.9 V for silicon carbide paste with granularity M10. Of electrocorundum paste with granularity M20, the readings varied from 0.15 to 0.45 V. The reproducibility of the results of the individual measurements was basically ± 0.01 V.

The results of measuring the properties of the molding pastes during ripening are shown in Fig. 2. In the first days, the readings increased by 20%, then the increase was 5 – 10%. In the electrocorundum pastes investigated, stable readings were established after seven days, while this occurred after eight days in the silicon carbide pastes.

A difference in the time for obtaining stable readings was established as a result of comparing silicon carbide pastes of the same composition but with a different ratio of fractions. In pastes with a high content of small fractions in the silicon carbide powders, the process lasted for 1 – 2 days. The difference in the granulometric composition of the abrasive materials used affected the rheological properties of the molding pastes in the article molding stage. For the same amount of water, the pastes prepared in the same conditions differed in the moisture content. In the case of material with high small-fraction content, the pastes were externally drier and the molding pressure was 1.5 – 2 times higher than the standard pressure. At a high content of large grains, the pastes were very wet and the molding pressure was approximately 1.5 times lower than the traditional pressure. The difference in the VIMS-1 readings for these pastes was 0.2 V. In the case of material with a high content of coarse fraction, it was necessary to decrease the amount of water for wetting the molding pastes of water in wetting the molding pastes, and when material with a high content of small-fraction grains was used, a larger amount of water was required for wetting.

The electrophysical properties of the pastes in conditions of low temperature and high humidity differed from the parameters of pastes made in standard conditions. When the temperature and humidity in the production premises changed the VIMS-1 readings for electrocorundum and silicon carbide pastes varied proportionally to the humidity —

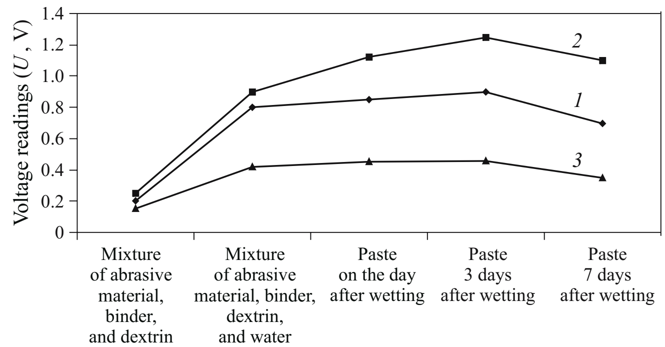

Fig. 2. Voltage readings by the VIMS-1 in control of molding pastes made of silicon carbide and electrocorundum micropowders: *1* and *2*) silicon carbide with granularity M14 and M10; *3*) electrocorundum with granularity M20.

TABLE 2

Composition of mixture	VIMS-1 readings (U, V) in measuring silicon carbide molding paste with granularity		Readings of VIMS-1 (U, V) in measuring electrocorundum molding paste with granularity M20
	M14	M10	
Abrasive material (AM)	0.52	0.52	0.18
AM + binder + dextrin	0.20	0.25	0.11 – 0.15
AM + binder + dextrin + water	0.70	0.90	0.38 – 0.47
Paste before molding	0.70	1.15	0.30 – 0.35
Dry paste	0.14	0.20	0.18
Paste in humid premises	0.80	1.28	0.40

they increased with an increase in the humidity and a decrease in the temperature. This means that the pastes absorbed water from the air, and when the temperature in the production premises increased, the pastes became dry and special methods had to be used for preserving the required moisture content in the pastes.

Based on the data obtained, we can conclude that each composition of abrasive paste has defined electrophysical parameters which can be estimated with the VIMS-1. In addition, measurements in production conditions showed that molding pastes can have different moisture content even in the same container. The paste deep in the container is thus usually wetter than on the outside, and the instrument readings at different points of the container will differ by 5 – 15%.

These examples of studying the effect of different factors on the electrophysical properties of micropowder abrasive molding pastes show that the properties of the pastes can be controlled with this parameter. Detailed studies of the dependence of the electrophysical parameters on the composition and the temperature-time conditions of preparing and storing the pastes will allow refining their composition and stabilizing the regimes for fabrication of molding pastes and molding.

The reported results show the presence of a correlation between the electrophysical properties and degree of suitability of an abrasive paste for molding, in other words, the plasticity and strength of the molding paste. Determination of the electrophysical properties of molding pastes for a tool made of silicon carbide and electrocorundum micropowders in a ceramic binder with the VIMS-1 does not require preliminary preparation of the samples and special equipment. This allows recommending the VIMS-1 instrument and the method of measurement of the electrophysical properties of molding pastes with the VMS-1 for controlling them in industrial conditions.

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